The syllable effect in anagram solution:

Unrecognised evidence from past studies.

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Abstract

Six previous studies of the variables affecting anagram solution are re-examined for the evidence that number of syllables contributes to solution difficulty. It was shown that the number of syllables in a solution word was confounded with imagery for one study and with digram frequency for another. More importantly it was shown that the number of syllables has a large effect on anagram solution difficulty in the re-analysis of the results from the other four studies. In these studies, the number of syllables was either more important than the principal variable examined in the experiment or the second most important variable. Overall the effect size for the number of syllables was large, $d = 1.14$. The results are discussed in the light of other research and it is suggested that anagram solution may have more in common with other word identification and reading processes than has been previously thought.

Recently Novick and Sherman (2008) provided evidence that good and poor solvers of anagrams are influenced by different types of information when solving anagrams. Specifically they found that “superficial features” of anagrams like pronounceability have a greater effect on solution difficulty for poor problem solvers, whereas “structural features” like the number of syllables have a greater effect on good anagram solvers. This study was novel partly because it looked at the difference between good and poor solvers but mainly because it was the first study to suggest that syllables have an effect on anagram solution difficulty. It is the latter discovery which is the subject of this paper, which will concentrate on the possible effect of the number of syllables on all participants, rather than the differential effect on good and poor solvers.

In many ways it is surprising that the possible role of the number of syllables has been ignored until now, as the literature on visual word recognition has suggested an important role for the syllable (Spoehr & Smith, 1973). There is also increasing empirical evidence that the syllable is an important unit in language production (Levelt & Wheeldon, 1994) and also in visual word processing (Ferrand, Segui & Grainger, 1996). Furthermore, it has been pointed out before that anagram solution could be conceptualized as a lexical access task (Fink & Weisberg, 1981), in which letters are re-arranged and then the solution word is retrieved from memory (Mendelsohn, 1976). As such is might be expected to share some of the features of other lexical access tasks. The literature on anagram solution, however, has tended to treat anagrams as outside of normal word identification or reading paradigms and, therefore, has ignored variables that have been shown to be important in these tasks.

This is not to propose a monolithic theory that explains all lexical access tasks including anagrams, nor to argue that the syllable is necessarily the link between all of these tasks. It is accepted that the tasks may be affected by similar variables because they might be analogous rather than homologous. It should also be remembered that the role of the syllable in other lexical access tasks is far from universally agreed. For example, Goldblum and Frost (1988) argued that the syllable was an important unit when solving crossword puzzle clues, but this was disputed by Srinivas, Roediger and Rajaram (1992). The role of the syllable in word naming and lexical decision tasks is also far from clear with many conflicting results (Stenneken, Conrad & Jacobs, 2007). For example, Ferrand, Segui and Humphreys (1997) observed a syllable congruency effect in word naming in which participants are quicker to name a word if they are given a syllable congruent prime, but this was not replicated by Schiller (1999). The role of the syllable may also differ between languages. For example, in Spanish visual word recognition, the syllable frequency effect is inhibitory but in English, syllable frequency has a facilitative effect (Macizo & Van Petten, 2007).

It is possible that an examination of the role of the syllable in anagram solution may shed light on some of these discrepancies. At the very least, however, it is hoped that it will confirm that there is a syllable effect in anagram solution and explain how most of us solve anagrams. In this paper previous studies of anagram solution will be examined for the possibility of a syllable effect on participants who have not been selected for their ability to solve anagrams. This syllable effect, however, may have been missed because the number of syllables in solution words has been ignored.

It should be noted that Novick and Sherman (2008) provide inadvertent evidence that the number of syllables is an important determinant of anagram difficulty in their screening pretest. This was an ecologically valid measure of anagram ability which contained 20 difficult five letter anagrams from those appearing in daily newspapers across the United States (Arnold & Lee, 1973). The anagrams were sinum, laveg, melip, yailg, oxmia, gunse, soule, mengo, limyk, vanie, wrope, watek, evirt; mykos, cuthe, pruns, mylad, suroc, doept, broep[1]. Novick and Sherman point out these "anagrams are difficult because they require several letter moves for solution or because their solutions begin with a vowel or contain infrequent letter combinations." It is also worth noting, however, that 12 of the 20 anagrams are multisyllabic, which we would argue makes a major contribution to their difficulty.

Many variables have been examined for their impact on the difficulty of anagram solution from word frequency, word concreteness, word imagery to bigram characteristics and anagram pronounceability (see Gilhooly and Johnson (1978) for a review). In this paper the results from six studies examining the variables which affect anagram solution difficulty will be re-examined. These studies were chosen because, as with all anagram studies before Novick and Sherman (2008) the impact of the number of syllables

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[1]The solutions are *minus, gavel, impel, gaily, axiom, genus, louse, gnome, milky, naïve, power, tweak, rivet, smoky, chute, spurn, madly, scour, depot/opted, probe.*

as a confounding variable was ignored, but for these studies sufficient detail was available to evaluate this impact. It will be demonstrated that for two of the studies, the number of syllables is as likely to have affected anagram solution as the proposed variable, and for four studies the impact of number of syllables will be quantified. In all cases the number of syllables was obtained from the English Lexicon Project (Balota et al., 2002).

Evidence suggesting confounding effects in results from earlier studies

Dewing and Hetherington (1974) looked at the effect of level of imagery (the ability of a word to evoke an image), on solution times of anagrams. Their ideas were based on an extension of Paivio's (1969) work on the importance of imagery in associative learning. In their experiments they showed that high imagery word anagrams were easier to solve than low imagery word anagrams. The anagrams were controlled for word length, number of solutions, letter order and frequency of letter pairs. However, four of the six low imagery words were disyllabic whereas only one of the high imagery words was disyllabic. It is, therefore, possible that this imagery effect was a number of syllables effect.

The results of an experiment by Mayzner, Tresselt and Helbock (1964) which looked in detail at the solution of difficult six letter anagrams, might also have been confounded by the syllable effect. They found that the word '*enigma*' was solved significantly more slowly (median solution time) than the word '*magnet*', which both have similar word frequencies. Their explanation relies on letter position digram frequencies (two letter sequences which are now called bigrams) which assess the frequency with which digrams appear in each position. They argued that *Enigma* has a lower digram total frequency than *magnet* and should therefore be harder to solve as the likelihood of each digram appearing in its position is lower. An alternative explanation might be that *magnet* has two syllables and *enigma* has three syllables.

Evidence for the direct effect of syllable number in re-analyses of previous results.

Up to this point it has been shown that two studies which claim to show the effect of a particular variable on anagram solution time have confounded that variable with number of syllables. There are, however, some studies in which it is possible to get more direct evidence of the effect of syllable number of anagram solution difficulty. All of the studies re-examined involve the solution of five-letter anagrams.

Ronning (1965) suggested that a “rule out function” was important in anagram solution, by which he meant that certain letter permutations were unlikely and could be “ruled out” of consideration as possible solutions. The experiments involved 20 participants solving 20 anagrams under timed conditions. Evidence is presented in favour of the rule out theory but the data also suggests that number of syllables could be an important factor. Three of the anagrams were disyllabic and these had significantly longer solution times (M = 153.33, SD = 46.18) than the monosyllabic items (M = 40.06, SD = 46.19; U = 3, z = -2.39, p = .017).

Mayzner and Tresselt (1966) conducted a study looking at anagrams with multiple solutions. The 80 participants in the study were asked to solve the anagrams under five different conditions, but from our point of view the conditions are less important than the effect of syllable number. There are 42 anagrams in the study of which 7 are disyllabic. There is a significant syllable effect on a Mann Whitney U test (U = 58, z = -2.18, p<.05) with the disyllablic words taking an average of 101.32 seconds (SD = 57.9) to solve and one syllable words taking 50.6 seconds (SD = 46.11), averaging over conditions. Furthermore, disyllabic words take longer in all conditions and although there is no main effect of conditions on a mixed model analysis of variance (F(4, 160) = 0.4, p =.781), nor a significant interaction between syllable number and conditions (F(4,160) = 1.24, p = .297), there is a main effect of syllable number (F(1,40) = 9.10, p = .004).

There is evidence that research which shows a strong effect of letter transition probabilities on time taken to solve anagrams, might also be explained by the syllable effect. Transitional probability refers to the frequency with which given letters follow or precede other letters in English words. Mayzner and Tresselt (1962) compared median solution times for nine anagrams with high and nine anagrams with low transitional probability totals which were matched for word frequency. Six of these words were disyllabic, and two of these had high transitional probability. Twenty-five participants took part in the study. From the results presented, it is possible to work out the correlation between transitional probability and solution time (r(18) = -.46, p = .053) and also the correlation between syllable number and solution time (r (18) = .54, p = .02). Furthermore, when a stepwise regression was conducted with transitional probability, bigram sum, log of Hal frequency (an objective measure of word frequency; Balota, Cortese, Sergent-Marshall, Spieler & Yap, 2004) and number of syllables as possible independent variables, only number of syllables and log of Hal frequency entered into the equation which raises the multiple *R* to .73 from .54 (see Table 1).

The most persuasive evidence for the importance of syllable number is provided by Gilhooly and Johnson's (1978) regression analysis on anagram difficulty. In this study, the impact of 12 variables on anagram solution difficulty of 80 randomly selected five-letter anagrams was examined in 45 participants. They found that starting letter, anagram solution similarity, pronounceability and two bigram frequency measures were most important in determining anagram difficulty. The most important of the bigram measures is called GTZero and is calculated from a bigram frequency matrix which gives the frequency of each bigram in different positions in a word (Mayzner & Tresselt, 1965). The matrix is generated with the rows representing the 20 bigrams that can be formed from the five letters of the word and the columns representing each of the 4 possible bigram positions, which are the first and second positions in the word (1,2), the second and third positions in a word (2,3), the third and fourth positions in a word (3,4) and the fourth and fifth positions in a word (4,5). Each of the possible bigrams can appear in each of these positions. So for the anagram IGHTL (Light), IG can appear in position 1 and 2, or position 2 and 3, or position 3 and 4, or position 4 and 5. This will be true for all possible bigrams, so IH can appear in position 1 and 2, or position 2 and 3 or position 3 and 4or position 4 and 5, and so on. The matrix will consist of 80 cells, each with a frequency entry taken from Mayzner and

Tresselt's (1965) tables. GTZero is the total number of cells, or bigrams in each position, with a frequency of greater than zero in the bigram frequency matrix. For example, for the anagram IGTHL (Light) HG, HT, HL, GT, TG, TL, LH, LG, LT would all have a frequency of 0 in the first position and overall LIGHT has a GTZero of 33. The more non-zero entries there are, the greater the possible competing solutions, which makes the anagram harder to solve (Mendelsohn, 1976). A program which will calculate GTZero and all of the other commonly used bigram statistics, for any word between 3 and 7 letters long from the Mayzner and Tresselt (1965) tables, is available at http://spider.dur.ac.uk/gtzero/index.html.

The Gilhooly and Johnson (1978) anagram set contains one (56), two (20) and three (4) syllable words. In the reanalysis, one and two syllable words were compared first. There was a significant effect of syllable number with one syllable words being solved more frequently ($t(74) = 2.13$, $p = .04$). There were 4 three syllable words and these were significantly harder to solve than both one and two syllable words ($F(2, 77) = 10.07$, $p < .005$). The percentage correct for each syllable type is presented in Table 2.

If the number of syllables had been included as a variable in the Gilhooly and Johnson analysis, it would have been the second variable entered in a stepwise regression, after GTZero and would have accounted for 13.7 % of the variance (see Table 3). GTZero is the only variable to be entered into a stepwise regression of their one syllable problems and has a multiple *R* of .48 (see Table 3).

The combined effect size of multisyllabic words against monosyllabic words for the studies which were reanalyzed is d = 1.14, assuming a random effects model, and the results are not heterogeneous (Q (3) = 3.42, $p > .05$). Overall there were 170 participants in the studies in which data was re-analyzed and 120 monosyllabic words and 40 multisyllabic words were used. To test the hypothesis that there is a significant difference of this magnitude at $p<.05$ with power of .8, would require a comparison of 22 words (11 in each group) with as many (22) participants.

Discussion

It is clear that there is a number of syllables effect on anagram solution with one syllable problems being solved more easily than two syllable problems and so on. It also seems likely that the effect applies to most people in that the participants of these studies were not selected to be good solvers. This is not to say that Novick and Sherman (2008) are wrong in arguing that there may still be a differential effect of syllables on good solvers, who may be particularly sensitive to it.

It seems likely that the syllable effect has been missed because anagram problems have generally been perceived as problems in letter rearrangement which are separable and, therefore, different from other research on word identification problems. This can also be seen in the way the pronounceability effect has generally been examined and discussed. Novick and Sherman (2008) describe it as “superficial” and something which is more likely to affect poor solvers. Yet the detrimental effect of pronounceability on anagram solution has been demonstrated on many occasions (Herbert & Rogers, 1966; Dominowski, 1966; Gilhooly & Johnson, 1978). It clearly suggests that phonemic encoding of anagrams takes place and is involved in some way in their solution, just as phonemic encoding plays a part in visual search, word recognition and reading processes (Conrad, 1964). Furthermore, Fink and Weisberg (1981) demonstrated that phonemic information could be used to improve the solution of anagrams as well as to disrupt it.

The evidence presented here suggests that anagram solution involves rearranging bigrams according to a series of hypotheses which are affected by the likelihood of bigrams in different positions. This is why GTZero is a very important variable for solution. When the word has many possible bigram frequency positions, it becomes more difficult to solve. This is true of any anagram regardless of the number of syllables in the word. When there is more than one syllable in the word, however, the anagram becomes more difficult to solve. This may be because a bigram is now split across two syllables and this may tells us something about the way the mental syllabary is organised (Cholin, 2008). Perhaps a more likely explanation is that words of more than one syllable often require bigrams that are otherwise infrequent, in that bigrams within a syllable tend to be higher in frequency than those across a syllable boundary (Adams. 1981). For example, to solve an anagram of *rugby* it is necessary to see the bigram *gb*, which is a very infrequent and, therefore, unlikely combination. This is how Seidenberg (1987) explained syllabic effects in tachistoscopic recognition. This suggestion could be investigated by comparing solution time for anagrams with relatively common bigrams across the syllable boundary to those with uncommon bigrams.

It would be possible to investigate explanations of the syllable effect in anagram solution further, by borrowing some research ideas from the work on the syllable's effect on speech segmentation (Mehler, Domergues, Frauenfelder, & Segui, 1981). For example, if Seidenberg's (1987) proposal, as applied to anagram research, is correct, then if we prime a solution to an anagram by providing a bigram, participants should solve the anagram faster if they are given the bigram that crosses the syllable boundary than if they are given another bigram. Furthermore, if we merely tell participants that the anagram is of a two or three syllable word this should make them realise that some seemingly unlikely bigram combinations are possible and also increase the speed and likelihood of a solution.

In future it is important that studies on anagram solution either control for the number of syllables or deliberately manipulate it. It is also suggested in future that anagram solution research should be examined in the light of, and inform research on, word detection and recognition. In that regard it is hoped that this paper will reinforce previous suggestions, which have been largely ignored (Fink & Weisberg; 1981), that anagram research should be related to lexical access tasks and reading processes in general rather than being seen as simply a problem of letter rearrangement.

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Table 1

Summary of Stepwise Regression Analysis for Variables Predicting Solution Time for Mayzner and Tresselt, (1962) (N=18)

Variable	*B*	*SEB*	β
Step 1			
Number of syllables	32.92	8.88	.67**
Step 2			
Log HAL frequency	-11.15	3.96	-.51*

Note. R^2 =.29 for Step 1; R^2 = .54 for Step 2 (ps<.05). *p<.05, **p<.01.

Table 2

Mean percentage correct for each syllable number in Gilhooly and Johnson (1978)

Number of syllables	Mean Percentage correct	Std Dev
1	59.29	18.33
2	48.22	24.05
3	16.67	10.34

Table 3

Summary of Stepwise Regression Analysis for Variables Predicting

Percentage of Successful Solvers for Gilhooly and Johnson (1978)

(N = 80 anagrams)

Variable	*B*	*SEB*	*β*
Step 1			
GTZero	-1.1	.26	-.4**
Step 2			
Number of syllables	-14.13	3.54	-.37**

Note. R^2 =.2 for Step 1; R^2 = .34 for Step 2 (ps<.05). *p<.05, **p<.01.

(N = 56 monosyllabic anagrams)

Variable	*B*	*SEB*	*β*
Step 1			
GTZero	-1.12	.28	-.48**

Note. R^2 =.2 for Step 1. *p<.05, **p<.01.